THESIS

submitted by

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for the

DEGREE PH. D., EDINBURGH UNIVERSITY.

PAPER I.

STRUCTURE and BIONOMICS of the WOOLLY APHIS - - Eriosoma lanigera (Hans.).

C O N T E N T S :-

(1) Introduction.
(2) Methods and Technique.
(3) Systematic position.
(4) Life-history and habits.
(5) General Morphology,
  (a) Wingless Female.
  (b) Winged Female.
(6) A note on Aphelinus mali (Hald) - The Woolly Aphis parasite.
(7) Lettering and Explanation of plates.
(8) Bibliography.

INTRODUCTION.

Eriosoma lanigera (Hausmann 1802), commonly known as the "Woolly Aphis" or "American Blight", is one of the most harmful pests of apple-trees. Though this insect is now very well known in almost every part of the world including Great Britain, America and New Zealand, and though detailed descriptions of its Bionomics have been published by various investigators, no observations seem to have been made on the life-cycle of this apple-pest in Scotland. This fact was brought to my notice by Dr. R. Stewart McDougall who thereupon advised me to take up the study of this insect.

I was further prompted to study this insect on account of the importance of the problem of its biological control. The white waxy material which is secreted by Eriosoma lanigera and under cover of which it remains protected, renders the aphis somewhat difficult to control by any of the commonly practised mechanical or chemical measures. Of late it has been reported by various entomologists that a certain Chalcid, named Aphelinus mali (Haldmann 1847), is parasitic upon this woolly aphis. This was an additional inducement to study this insect.

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I wish to take this opportunity of acknowledging my sincere thanks to Dr. R. Stewart McDougall for his kindly supervision throughout the course of investigation of this problem, the work being done in the Entomological Laboratory at the University of Edinburgh. My thanks are also due to Dr. Thomas V. Campbell for his frequent help in outdoor collections of the woolly aphis. I am also indebted to Professor J.H. Ashworth for obtaining access to private apple orchards.

METHODS and TECHNIQUE.

To provide a continuous supply of live woolly aphis, 12 potted apple plants were kept in the Laboratory and infected with Eriosoma lanigera. In a short time the aphis had established itself on the offered plants. At the same time out-door observations were carried out on infected apple trees in private orchards and gardens. Experiments in biological control of this aphis by means of its Chalcid parasite - Aphelinus mali - were carried out on garden trees as well as on potted plants in the Laboratory.

Living specimens were dissected in salt solution under the binocular. Of the various killing and fixing agents, Carnoy's fluid gave the best results/

results, the formula being:-

Absolute alcohol ...... 6 parts.
Chloroform .... 3 parts.
Glacial Acetic acid.... 1 part.

For staining purposes, Haematoxylin(Delafield) and Eosin were used. In the case of the study of skeletal structures the specimens or parts of them were boiled in 10% caustic potash and washed thoroughly before examination. In making permanent preparations for the microscope the general method was:-

(1) Boil in caustic potash.
(2) Wash in distilled water.
(3) Place in acetic acid.
(4) Stain while in the acetic acid by adding a few drops of acid fuchsin.
(5) Wash in a bath of 40% to 50% alcohol.
(6) Dehydrate by taking the preparation through 60%, 70%, 90% up to absolute alcohol.
(7) Clear in xylol.
(8) Mount in balsam.

Figures were drawn from permanent preparations by means of the camera lucida.

Dissections of parasitised aphids which become black and hard, proved at first somewhat difficult owing to the hardness of the chitinous covering. The following method, however, gave fair results.

The parasitised aphid was transferred to a clean hollow slide and a drop of Carnoy's fluid added. This reagent reached and fixed the Aphelinus parasite situated within the body of the host. The specimen was/

was then placed under the binocular. By means of fine needles the anterior region of the parasitised aphis was broken into, and another drop of Carnoy added to assure that the parasite had been reached. During this treatment the parasite sometimes floated out and when this did not happen the parasite was quite easily separated from the hard chitinous covering of the host.

SYSTEMATIC POSITION.

Eriosóma lanigera belongs to the family Aphididae of the order Rhynchota. Within this widely distributed family, it is placed under the subfamily Eriosomatinae, with Eriosoma as the Generic name. This insect is popularly known as the "Woolly Aphis" on account of the white waxy wool-like stuff secreted by glands on its dorsal surface. It is also usually spoken of as the "American Blight" owing to the popular idea that the United States of America was the original home of this insect. This point of the original home of the woolly aphis has been much discussed by various entomologists, and is still in an unsettled state. Theobald(4) and Davidson(8) believe in its European origin. Baker(9), on the other hand, who has made an exhaustive study of this insect in the United States, believes the original home of E./

E. lanigera to be the great limestone regions of Temperate America. Whichever might be the original place of this aphis, carried in commerce it has now become quite cosmopolitan in its distribution.

As to the Generic name of our insect, there is still academic debate. Baker(9) has given a detailed historic account and uses the name Eriosoma. Schizoneura, however, as the generic name is also in use.

LIFE - HISTORY.

As described by Baker(9) in the United States, E. lanigera takes a year to complete its life-cycle, two host trees of different species - Apple and Elm - being required. The life-history as observed in America is as follows:- The egg, laid in winter upon the bark of elm in crevices, hatches in the spring and gives rise to the so-called Stem-mother. After she is fully developed, the stem-mother produces, by the middle of April, a new generation viviparously and parthenogenetically. This second generation, wingless in structure, produces in turn, early in May, a third generation by the same mode of reproduction. Insects of this generation are winged and many of them fly to apple in early June. Here these winged forms produce/

produce the fourth generation which, wingless in structure, give birth to another, the fifth, which is exactly like it. Aphids of the fifth generation produce, by the middle of August, a generation of winged forms, the sixth generation. At the approach of autumn, insects of this generation migrate to the elm where they settle upon the bark and produce sexual forms - males and females - the seventh generation. These mate, and the female deposits her fertilised egg in a crevice of the bark where it passes the winter to hatch as a stem-mother the following spring.

Observations in England indicate that the life-cycle of E. lanigera is different here from that passed through in America. The woolly aphis in England, instead of alternating between elm and apple, confines itself to the apple plant; and further the sexual generation on the elm, as described in America, has been very rarely recorded here, and even then without the elm playing a part(4).

Field observations: In spite of my continued searching in my outdoor work, I only once found the so-called stem-mother, and this in the second week of April 1928. The Stem-mother(fig.1) is stout and more or less round in form. Its legs are rather short/

short; the antennae also are short and are characteristically five-jointed. Its method of reproduction was viviparous and parthenogenetic, and the young forms produced developed into the Spring Apterons Viviparous Females. Almost everywhere in my observations it was the Spring Viviparous Female that made its appearance on apple trees, late in the month of April. The method of reproduction of this Spring Female was parthenogenetic and viviparous; and generations after generations were being produced by the same mode of reproduction throughout the whole summer. At the end of October their numbers began to decrease gradually; many of the aphids, especially the young forms, dying partly from over-crowding and partly from cold. A few adult aphids, at this time, were found seeking crannies and crevices for shelter and here they were observable throughout the winter. It has been also recorded that some of the forms, at this time, migrate to the roots in order to pass the winter below there[10,14]. By the end of November no visible trace of the woolly aphis could be seen on any of the infected apple trees. The forms that were found hibernating in crevices and under bark and such other sheltered places became active again in/

in the following spring, about the middle of April, and after feeding proceeded to multiply parthenogenetically and viviparously.

Laboratory observations: In addition to these out-door observations, I had colonies of E. lanigera on potted apple plants in the Laboratory, and these were under my direct observations day by day. The Laboratory observations, during 1928, yielded some interesting results. In the second week of August 1928, I observed, for the first time, a winged E.lanigera on one of the potted apple plants. Soon afterwards winged forms were found in enormous numbers. The nymphal stage characterised by a greatly modified thorax and two pairs of wing-pads lasted about ten days. Then moulting took place and winged adults appeared. The winged forms either remained on the same plant or flew to other apple plants and reproduced their kind parthenogenetically and viviparously. This production of winged forms on the Laboratory plants began to lessen towards the end of October, and about the second week of November hardly any winged form were to be found. The reduction in numbers in the case of the wingless E. lanigera on the approach of winter noted above as happening in the open, did not take/

take place in the case of the Laboratory forms which continued to live, under Laboratory conditions, without any change in their mode of life.

The out-door observations during 1929 were made on infested apple trees in various private gardens, and especially on trees in the Edinburgh Zoological Park. Life of the Woolly Aphis continued on the same plan as observed during the previous year, but in addition, winged E. lanigera were observed in the open. They were first noticed in the last week of August, and they continued to be produced in abundance throughout September. In October there was a change in the weather to wind and cold, and as a result the winged forms of Woolly Aphis began to decrease in number. By the end of October the winged forms had completely disappeared. Wingless individuals could still be found exposed during November, but by the end of the month none remained on the outside of the plants; only a few could be observed in shelter places and under bark.

In my out-door observations I never found, in spite of search, E. lanigera on Elm trees. As a control and for comparison, a number of potted young Elm plants were kept in the Laboratory. These were placed/

placed in the neighbourhood of the infested apple plants, but in no case was there a passage of winged E. lanigera from apple to elm. Winged forms transferred to the Elm and placed in position did not seem at home. None remained on Elm, some died and others soon left. Incidentally no apterons forms passed to the Elm, and their experimental transference proved of no avail.

HABITS.

The mouthparts of the Woolly Aphis consist of bristle-like mandibles and maxillae. They are thus modified for piercing the bark of the apple plant and sucking in the sap of the host. Wounds in the bark or cut branches are favourite places of attack by this insect. The aphis multiplies very rapidly and on an enormous scale, with the result that within a few days the whole plant becomes covered by this aphis, hidden or almost hidden in its waxy secretion. Such a heavy and rapid infestation results in the formation of gall-like swellings and cankerous outgrowths on the apple. On the Laboratory potted plants the infestation was so severe that gradually plant after plant succumbed to the attack.

Baker[9] describes how the leaves of the apple/

apple plant, consequent upon the attack of this aphis, become curled. In my laboratory as well as out-door observations I could not find this type of damage. The Woolly Aphis, so far as my observations go, does feed on buds and leaves, in its young stage, but is never at home there; its natural habitation is the stem.

The method of feeding of this aphis was carefully watched, and may be thus described:- Usually when the aphis is at rest, the proboscis lies along the underside of the body, between the coxae. When, however, a suitable feeding place is found E. lanigera raises the forepart of the body on its front pair of legs and brings the proboscis into a more or less vertical position. The labial sheath which acts as a guide, just touches the bark. So guided the bristle-like mandibles and maxillae are introduced into the tissue of the plant. The aphis then moves a little backwards, takes a firm grip of the substratum by means of its front and hind pair of legs, and begins to suck in the sap of the host plant. The feeding action can very well be seen, as indicated by the up and down movement of the head region. During feeding the antennae are held at right angles to the head.

Davidson/

Davidson(8) discusses the origin of the cankerous out-growths on the apple-plant. He cites the works of Riley(1879), Blomfield(1906) and Grove (1909) and concludes that the question, as to whether some poisonous ferment secreted by the salivary glands of the Woolly Aphis, and poured into the wound, causes the swellings, is not yet settled. He himself in agreement with Theobald(4), traces the origin of the cankerous growths to the canker fungus Nectria ditissima. The Nectria spores gain entrance to the wounds, germinate there and the resulting mycelium produces the cankerous outgrowth.

In concluding this account of the habits of Woolly Aphis, I wish to add a few observations made in the Laboratory, concerning the length of life and the rate of multiplication of the wingless viviparous female. Newly-born aphids were isolated on separate branches of the apple plant. The particular portion of the branch to which the young form was transferred, was disconnected from the rest of the plant by means of a round shield of thick paper. Through a hole in the centre of the shield the branch was passed, no space or chink being left through which the aphids might make their way. The paper was made gummy so that no aphids could pass from the isolated part of the branch by that way. Details of the observations are summarised in the following table :-

Specimen.	1	2	3	4	5
Date of birth.	28.5.29	16.7.29	15.7.29	16.8.29	16.8.29
Date of first moult.	3.6.29	20.7.29	19.7.29	24.8.29	21.8.29
" second moult.	11.6.29	23.7.29	22.7.29	28.8.29	25.8.29
" third moult.	16.6.29	26.7.29	24.7.29	31.8.29	29.8.29
" fourth moult.	X	29.7.29	28.7.29	5.9.29	X
Date it began to reproduce.	17.6.29	30.7.29	29.7.29	6.9.29	30.8.29
Date it stopped reproduction.	4.7.29	17.8.29	17.8.29	20.9.29	7.9.29
Total number of forms produced.	77	64	113	68	29
Maximum number during 24 hours.	13	5	10	6	5
Length of life of the aphis. = days	38	32	33	36	22
Average temperature.	65°F.	65°F.	65°F.	63°F.	62°F.

On an average the length of life of the spring viviparous female varied between 22 and 38 days. With regard to multiplication, the maximum number of young ones produced by a single viviparous female was 113 during a period of 18 days, at a temperature varying between 59°F. and 72°F. The maximum number of young ones produced during 24 hours, as observed in the case of another individual was 13. With regard to the number of moults, four seemed to be a common number. The number of days intervening between one moult and another depended upon the temperature and the food-supply. Maturity was attained in a variable time, from 14 to 21 days. The period of productive life was, on an average, 20 days in warm weather conditions.

MORPHOLOGICAL DESCRIPTION.

An anatomical description of the spring viviparous female has been given already by Davidson(8) in England and Baker(9) in America, and so it is needless to repeat it here. So far as I am aware the morphology of the winged stage has not been described as yet in detail, although there are short sketches in Baker's publication. I therefore give a general outline of the morphology of the wingless viviparous female, and describe in detail that of the winged form.

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THE WINGLESS VIVIPAROUS FEMALE.

The wingless viviparous female (fig.2), waking up in spring from her winter sleep, begins to secrete large quantities of the protective waxy material, and proceeds to the work of parthenogenetic reproduction. If the wax be removed by means of gentle brushing, the aphis is revealed as a dark brown insect, oval in form, and with a slightly more elongated body than that of the stem-mother (fig.1). The body is much swollen, owing to the presence of the large number of embryos developing in the ovary. The three typical regions, the head, the thorax and the abdomen are quite distinct.

The head (hd;fig.3) is strongly bent under the anterior end of the body, and the proboscis(pb.) when not in use, lies pointing backwards, along the ventral face of the body, usually extending as far back as the base of the coxae of the third pair of legs. The proboscis (fig.4) consists of a sheath-like four-jointed labium(lb.) within which lie the bristle-like mandibles(md.) and maxillae(mx.). The dorsal portion of the proboscis, at its base, is partly covered over by a short shield-like labrum(lbr.). A little behind the proboscis, dorsalwards and out-

wards/

outwards, are the antennae(ant.) made up of six joints as compared with the five-jointed antennae of the stem-mother. The last two joints bear sensoria(sns.). The sensory organ of the fifth joint (fig.5,sns.^{5}) is a circular pit fringed all round with prominent hairs. The sensorium of the last joint (fig.5,sns.^{6}) consists of a slight depression showing four dark dots surrounded by a circle of small hairs and an outer semicircle of larger ones.

Just behind the antennae and a little to each side, are the eyes(e) situated on a round protuberance, each eye consisting of three ocelli arranged in a triangle.

Behind the head comes the thorax (fig.2,th.) made up of three segments, each provided with a pair of legs. Each leg (fig.6) consists of a small but stout coxa(c.), a short trochanter(t.), an elongate femur(f), a long slender tibia(tb), and the tarsus(ts). The tarsus is composed of a small basal joint(ts.^{1}) and a longer slightly curved terminal one(ts.^{2}); the latter carries a pair of curved claws(cl). Each joint of the leg bears a few small hairs scattered here and there.

The thorax is followed by the abdomen(abd.) of/

of eight visible segments, the terminal one being very much reduced. At the hind end is situated the anus below which opens the genital orifice; between these two and separating them is an anal plate(an.pl.) lined with prominent hairs.

The spiracles (fig.3,sp.) are situated in the pleural region. The first spiracle($sp.^1$) lies between the first and second coxae on each side. The next pair($sp.^2$) behind it, is situated more or less on the borderland between the mesopleurae and metapleurae. Then follow the abdominal spiracles(sp.abd.) 7 on each side.

The dorsal surface of the aphis is characteristically set with a type of dermal structures known as the wax-glands(w.g.) arranged in regular rows on head thorax and abdomen. Each gland (fig.7) is composed of several polygonal areas surrounding a central facet, beneath which are situated large glandular cells. The latter secrete a white waxy substance which enters the central wax-chamber from which it passes out in the form of long fine woolly filaments. This waxy secretion is most abundant in the caudal region of the aphis, where it forms beautiful ribbon-like streamers.

On/

On the dorsal side of this insect, between the fifth and sixth abdominal segments, one finds a pair of structures known as the cornicles(cn.). Unlike the tubular shape found in other aphids, the cornicles of Eriosoma are characteristically on a level with the dorsal surface. Each cornicle consists of a ring-like opening, chitinised in its anterior half margin, and connected internally by means of a duct with a central wax reservoir. In living condition this reservoir contains a semifluid yellowish substance which hardens into a solid whitish mass on exposure to the air.

In observing the aphids, I found that on gentle pressure on the abdominal region, the aphis responded by putting to the outside from its cornicles the semifluid wax which at once hardened on exposure to the air. It was also noticed that quite half an hour had to elapse before the aphis was capable of putting out another quantity of the secretion. The cornicular secretion differs in colour from that of the numerous other wax glands, being yellow rather than whitish, and also in not forming long filamentous threads.

The question as to the possible function of the/

the cornicles has been historically treated by Davidson[8]. He cites Horwath(1904) and Gillette(1908) who are of opinion that the wax-fluid from the cornicles "affords a means of protection against the predaceous larvae of Coccinellidae and Chrysopidae". It is very difficult, however, to understand how the comparatively small secretion of the cornicles can act as protective, in view of its being hidden by the more abundant mass from the ordinary wax-glands; (and yet there must be some function when the two secretions differ from each other).

For a long time these cornicles were believed to secrete honey-dew; but this belief has now been completely abandoned. The so-called honey-dew of aphids, which attracts ants and other insects, is exuded at the anal orifice, in the form of clear, sticky globules which may be seen remaining attached to the tip of the abdomen or entangled among the white threads.

As mentioned before, the method of multiplication of the spring viviparous female of E. lanigera, as well as that of the succeeding generations, is parthenogenetic. The young aphids produced (fig.8) are orange-like in colour, elongate in form and have a proboscis(pb.) longer than the body. The antennae at this/

this stage are only five-jointed. As development goes on and moults take place, the young forms attain their normal size in due course. They now much resemble their spring viviparous mother and the antennae are now six-jointed.

While observing the growth of the aphis from the young to the fully mature stage, it was noticed that the additional joint in the antenna of the adult is in reality a modification of the third joint, which, as development goes on, constricts itself into a longer proximal portion corresponding to the third joint and a smaller knoblike distal piece representing the fourth joint of the mature aphis.

WINGED VIVIPAROUS FEMALE.

The first stage in the development of the winged form begins with an external differentiation in the thoracic region of the young forms of E.lanigera. The thoracic segments grow a little larger in size and soon become quite distinguishable from the head region in front and the abdomen behind(fig.9). After a day or two small pale yellowish outgrowths(o.g.) appear on both sides of the meso- and meta-thorax. These later on develop into the so-called wing-pads (fig.10,w.p.). Under cover of these pads, wings are developed/

developed, and when this nymphal stage has reached its full development these pads appear deep-brown in colour. The body of the nymph is more or less of a general brownish colour, and it is covered over with a powdery wax mixed with a few long waxy tufts, especially in the dorso-caudal region. As this stage progresses the production of wax decreases. The nymphal antennae which in its early stage are five-jointed, now become six-jointed. In the fully developed nymph, the newly formed sensory rings could be easily seen under cover of the antennal sheaths. A little behind the ocular tubercles are the compound eyes of the adult winged stage, recognizable by the presence of orange-brown pigment. Similar brown pigment was also seen in those places where later on would be developed the three ocelli of the adult stage. The mouth-parts and other structures resemble those of the apterons female. In behaviour and habits the nymphal form is quite normal; it moves about and feeds just like the wingless female.

The nymphal stage lasts from eleven to twelve days. The length of the period required by the winged form to complete its nymphal stage was ascertained by means of an experiment. On one of the/

the laboratory potted plants a small portion of a branch infested by this aphis was marked out and isolated from the rest of the plant by fixing two circular pieces of thick paper, one below and the other above the isolated portion. Then every form of aphis on this portion was inspected, and only those forms which had not as yet shown any thoracic differentiation, were retained on the isolated branch, all others being removed. The next morning an examination of the aphids on this experimental branch portion showed two small young forms with a little differentiated type of thorax. The date was noted and these forms were kept under observation every day. From the date of their first differentiation in the thoracic region these two forms took 12 days to complete all their nymphal growth before they gave rise to the adult winged stage.

The freshly emerged winged viviparous female of E.lanigera(fig.11) is pale brown in colour, with a yellowish stigma on the wing. After a few days, however, the colour of the body changes to deep-brown in the abdominal region, the head and thorax becoming darker in shade. The stigma too changes to grey-green. The body of the winged form is divisible into head, thorax/

thorax and abdomen. In a series of measurements, the greatest length of the winged female was found to be 1.5 m.m., and the greatest breadth in spread of wings was 6 m.m.

Figures 12, 13, show the dorsal and ventral views of the head of this winged form. The mouth-parts resemble those of the wingless female; but in many other respects the head of the winged female differs from that of its wingless cousin. The antennae(ant.) are six-jointed; the last four joints bear the sensory rings(sns.r.) and in addition the last joint carries two small sensory pits (fig.14,sns.p.) fringed with small hairs. Each sensory ring is situated on an elevated ridge passing almost round the joint and thus giving the sensorium an annular appearance, complete on the ventral side, but incomplete on the dorsal face of the antennal joint.

The sensoria on the right and left antennae of the same individual do not agree in number. Neither do the numbers correspond in the various individuals of the same species. Reference to the following table will make these points clearer :-

Specimen/

Specimen.	Number of the antennal joint.	Number of sensoria on Right antenna.	Number of sensoria on Left antenna.	Specimen.	Number of the antennal joint.	Number of sensoria on Right antenna.	Number of sensoria on Left antenna.
1.	3	22	22	8	3	18	16
	4	4	5		4	3	3
	5	6	5		5	5	4
	6	2	3		6	1	2
2.	3	21	23	9.	3	16	20
	4	4	5		4	3	4
	5	5	4		5	5	5
	6	1	1		6	1	2
3.	3	20	18	10.	3	15	18
	4	4	4		4	3	4
	5	4	4		5	4	5
	6	1	1		6	1	1
4.	3	22	23	11.	3	23	20
	4	4	3		4	5	4
	5	4	4		5	6	6
	6	1	1		6	2	3
5.	3	23	20	12.	3	20	16
	4	5	5		4	4	4
	5	5	4		5	4	3
	6	2	3		6	1	1
6.	3	21	21	13.	3	19	20
	4	5	5		4	4	5
	5	5	4		5	3	3
	6	2	2		6	1	1
7.	3	20	21	14.	3	21	18
	4	5	4		4	5	4
	5	4	3		5	3	3
	6	1	1		6	2	1

Of the other head structures, a pair of compound eyes(e.c) are situated in the outer corners of the base of the antennae. Each eye is made up of a large number of circular, slightly elevated, transparent facets. At the posterior ventral margin of each compound eye is situated an ocular tubercle(o.t.) bearing three small transparent lenses, corresponding to similar structures on the head of the wingless female. In addition to the compound eyes there are three conspicuous ocelli(oc.) situated on the head capsule of the winged form, in the form of a triangle.

Behind the head and connected to it by means of a small narrow neck, comes the thorax composed of three segments - the prothorax(p.), the mesothorax(ms.) and the metathorax(mt.). Of these the prothoracic and metathoracic regions are relatively small and narrow; the mesothorax is most highly developed and occupies quite a large area of the thoracic region.

The prothorax (fig.15) is collarlike in form and partially hidden from above by the overhanging front portion of the mesotergum. The prothoracic tergum (fig.15,p.tg.) is only slightly chitinised on its anterior margin. At the sides there is a/

a thin or at most thinly chitinised pleural plate(p.pl.) which ventrally gives attachment to the coxae(c.) of the front pair of legs. The pleural plate sends inwards a small knoblike projection(k.p.) which extends almost to the base of the ocular tubercle. The sternal portion of the prothorax(p.st.) is wholly transparent and unchitinised. (From this part issues, in front, the labial sheath.)

The mesothorax (fig.16), the most prominent portion in the thoracic region, is modified to give rise to several distinct structures. In the tergal region the front portion or the prescutum(psc.) is triangular in form and pointed behind. The cephalic extremity of the prescutum extends obliquely forwards on the prothorax, forming a small projection known as the anterior phragma(a.p.). On each side and behind the prescutum is situated the scutum(sc.) divided into two large elevated portions. Between these two scutal portions runs a deep furrow(fr.) which bifurcating anteriorly, runs forward on either side of the triangular prescutum holding the latter, as it were, within its arms (fig.16). Behind the scutal region, in median line, is the oval-shaped scutellum(scl.). Posterior to this comes the post-scutellum(p.scl.) as shown/

shown in figure 16. In its mid-posterior region the post-scutellum is tucked in a little, and passes under the metathorax(mt.) which runs over it like a narrow band. The tucked-in portion is named by Baker[9] the posterior phragma. On each side the ends of the post-scutellum are connected to the pleural region just in the neighbourhood of the pleural wing-process (B) to be described later on.

The mesosternum (fig.17) is incompletely divided into four parts by two sutures running crosswise to each other. The posterior corners of the mesosternum show a semicircular excavation on each side; into these are received the coxae(c) of the second pair of legs. From the anterior corners of the mesosternum arises a shoulderplate(sh.pl.) which is continued back up to the point of attachment of the coxae(c.).

On its inner surface (fig.18) the mesosternum shows two deeply chitinised ridges(rg.) running crosswise to each other, and corresponding themselves to the two sutures which, as said above, divide the mesosternum externally into four incomplate parts. From the posterior portion of the longitudinal ridge arises a prominent endosternite (end) unpaired at its base/

base and with two free distal arms(ar.). The arms are bent upwards and between them a small blunt process(pr.) runs forward. Viewed from the anterior side, the endosternite appears like the vertical section of a champagne glass (fig.19). Viewed from the sides the stalk of the sternite appears rather flat at its point of origin, and so are the arms seen from above.

The pleural region of the mesothorax(fig.16) is most complex and is composed of a number of chitinised pieces and plates involved in the attachment and support of the mesothoracic pair of wings. Arising from the pleural margin of the shoulder plate (sh.pl.) can be seen a plate-like chitinous structure divided into an anterior flat portion(A.) and a posterior conical rodlike one (B.). Both of these parts are thickly chitinised thouh not uniformly. From the dorsal margin of the anterior plate (A.) two structures arise; one, the anterior, in its relative position, (C) is semicurved with forked ends by means of which it gives support to the basal portion of the anterior notal wing-process of the scutum(sc.m.a.). The other structure (fig.16,20.D.), posterior in position to the first, is somewhat interesting.

Situated/

Situated obliquely, it consists of a long stalk expanded at the free end into a flattened structure which supports the basal part of the mesothoracic wing on its ventral side.

The chitinous rodlike sclerite named B in figures 16, 20, ends dorsally into two conical processes(pr.^{1} ,pr.^{2}) just below the base of the wing. The posterior process(pr.^{2}), curving backwards, fits into the third wing-sclerite(w.sl.^{3}) to be described later on. At the base of this rodlike pleural sclerite (B) the pleural region is tucked inside, within the thoracic cavity, in the form of a hollow blunt process on each side (fig.16 hp.). The anterior margin of the meso-pleural region is lined by a rodlike chitinous humeral portion of the tegum(fig.16 E), which extends downwards at the sides to be received into the notch between the shoulders of the sternum and the pleural plate (A).

Having described the mesopleural region, let me deal now with the basal sclerites of the mesothoracic wings and the notal modifications of the scutum involved in wing-attachment.

The notal margin of the scutum shows two distinct modifications; an anterior notal wing process (fig.16,21,sc.m.a.) and a posterior one (sc.m.p.).

The/

The anterior notal wing process is supported, as mentioned before, by a buttress-like forked extension (fig.16 C) from the pleural side. At the point of junction between the anterior notal process and the posterior one, is developed a very complex and strongly chitinised structure which can be better studied by looking at the Figures 21, 16, F. It has a concave depression, its anterior side is bent outwards upon itself, thus affording a twofold arrangement for the articulation of the first two wing sclerites.

At the base of the wing there are four sclerites, three dorsal and one ventral. The first sclerite(fig.21,w.sl.$_1$) is situated at the anterior margin of the base of the wing; it is a long chitinised rod with a hook-like ending which, as stated above, fits into the notch made by the upturning sides of the 'notal structure'(F). The second sclerite(w.sl.$_2$) is a flat chitinous plate, placed obliquely and terminating in a pointed end; the latter is received into the concave depression of the 'notal structure'(F). The third sclerite(fig.20,22,w.sl.$_3$) which is situated on the ventral side of the wing-base, has a notch into which, as stated before, fits the claw-like stout process(pr.2) of the pleural wing plate/

plate (B). It thus constitutes a pivotal arrangement for the movement of the wing. The fourth sclerite(w.sl.4) which comes into action only when the wing is being spread, is situated at the posterior corner of the wing-base. By means of the three blunt processes, with which it is equipped, it engages with the posterior notal wing-process(fig.21 sc.m.p.) thus helping to keep the expanded wing in position. At the anterior proximal corners of the wing, there is a small wing extension known as the Tegula.

The metathorax (fig.16,23,mt.) is a narrow, transverse, band-like structure. The metasternum (fig.23) has on its anterior margin two hollow tube-like processes(tp.) which project into the thoracic cavity. A little behind these processes, in the posterior corners of the metasternum, articulate the coxae(C) of the third pair of legs. The pleural region of the metathorax which gives attachment to the hind pair of wings, can be better studied by reference to Figure 24. At the base of the hind wing (fig.25) are two sclerites; one, the anterior, (sl.) is applied to that portion of the metapleural sclerite marked as X; the other, situated in the posterior corner(sl.2) engages itself with the pleural sclerite/

sclerite marked Y in Figure 24.

Venation of the Wing:- A comparison of the wing-venation of E. lanigera with that of Schizoneura americana drawn by Miss Patch and quoted by Comstock in his "Wings of Insects", shows that the venation is much the same in both cases. As in S. americana, the costal margin(fig.26,cst.) in E. lanigera is stiffened by the probable fusion of the costal vein with it. There is also present, as in S. americana, the 'large main vein channel'(v) ending in a stigma, and constituted by the fusion of the sub-costa, radius, median, cubitus and the first anal. R1 and Radial sector(R.s.) are likewise present here, and so is the median which forks into m_1+2 and m_3+4. The cubital(cb.) is single and so is the first anal(a_1).

There is, however, one point of difference between the venation of E. lanigera and that of S. americana, and it is this:- if a straight line be drawn by joining the point of origin of the radial sector to the point where the cubital terminates, it will be found that whereas in the case of S.americana the said straight line intersects the median before the lstter forks into m_1+2 and m_3+4, in E. lanigera it/

it cuts the median after its bifurcation. This distinguishing point in the wings of E. lanigera and S. americana, first pointed out by Baker(7) has been confirmed by me after examination of a number of wings of E. lanigera.

The venation of the hind wing (fig.27) consisting of the radial sector(R.s.) the median(m) and the cubital(cb.) corresponds in all respects to that of S. americana.

The fore and the hind wings are joined to each other by a series of hooks (fig.27,28,hk.) situated on the costal margin of the hind wings; the hooks are received into a fold formed by the turning under of the hind margin of the front wings.

Abdomen (fig.23) :- Following the thorax is the abdomen(abd.), broad and swollen with the growing embryos within the ovary. The wax-secreting glands together with a pair of cornicles(cn.) are present on the dorsal surface of the abdomen. The anus is situated posteriorly; below it lies the genital opening(gn.op.), and between the two is placed the anal plate, lined with a series of marginal hairs.

As in the case of the Spring Viviparous Female there are 9 pairs of spiracles present in the Winged/

Winged Female. The prothoracic spiracles are situated in the pleural region of the prothorax; the metathoracic pair is situated in the metapleural region, a little above and between the coxae and the base of the hind wings. The remaining seven pairs are situated at the sides of the first seven abdominal segments.

Wax-glands :- There are no wax-glands on the head and the thorax of the Winged form. The abdominal region, however, has a number of secretory glands on its dorsal surface. These wax-glands of the Winged form show a difference in structure from those found in the Wingless female. Under the microscope (fig.29) they are seen to be not only smaller in size but also less clearly outlined than those of the Wingless female (fig.7). Consequently the production of waxy material is very much limited. This seems to be quite in consonance with the insect's habit of flying; otherwise the presence of waxy material, without being of much use to it, would interfere with its flight. However, when the winged forms settle down to reproduce their kind, the waxy material is secreted to protect the young ones produced; but even then the production of wool is not so rich in quantity as in the case of the wingless female.

A note on Aphelinus mali (Hald.) - The Woolly Aphis parasite.

In working with the 'woolly aphis' I had hoped to be able to include a series of experiments on the life-history of Aphelinus mali - the Chalcid parasite of Eriosoma lanigera - especially with a view to see if it could be possible to introduce this parasite in Scotland as a check against the woolly aphis. Through the kindness of Mr.J.C.Fryer of Harpenden and Dr.Thompson of Farnham, I had the privilege of receiving some material of Aphelinus during the summer of 1928. Lack of time, however, has prevented the carrying out of detailed experiments and observations. All I have been able to do was to perform two sets of experiments; one on out-door apple-plants, and the other on the Laboratory plants.

In order to provide for a successful breeding of A.mali, small tin cages with a circular form were prepared (size, diameter 7", height 3½"). These cages were provided with very fine wire gauze on their flat sides, so as to prevent the escape of the parasite from the cage. The method of fixing the cages to the apple-plant consisted in 'threading' the branch of the tree through a hole made in the sides of the lower lid of/

of the cage, and fixing it tightly with grafting cement. (Please see the photographs at the end). The details of the experiments are as follows:-

<u>Experiment I.</u>:- On the 31st of July 1928, two of the wire-gauze cages described above were fixed to separate branches of an apple-plant in a garden. The branches chosen were heavily infested with Woolly Aphis. The parasites - A.mali - were introduced to each of these cages. After about three weeks, on 25th August, the cages were opened, and it was found that 4 aphids were parasitised in one cage and 6 in the other. One blackened aphis from each parasitised lot was dissected, with the result that in one was found a fully developed larva of the parasite and the other contained a young Aphelinus pupa. The parasitised aphids were then kept under observation every day. Adult Aphelinus emerged from the host on 8th and 9th September. The life-cycle of the parasite took about 38 days, in the open, at an average temperature of 60°F.

<u>Experiment II.</u>:- On 31st July 1928, two similar cages were fixed on potted apple plants in the Laboratory, and the aphis-parasites were introduced to each cage. On 22nd August, when the cages were opened/

opened, 8 aphids were found parasitised in one cage and 11 in the other. A dissection of one parasitised aphis from each box, yielded a pupa in each case. Adult Aphelinus emerged from the parasitised aphids on the 3rd and 4th September. The life-cycle of the parasite, indoors, took 33 days, at an average temperature of $65^{o}F$.

Temperature thus seems to be an important factor regulating the period of life-cycle of this Woolly Aphis parasite. In his memoirs on the Biological study of Aphelinus mali, Lundi[13] says that the life-cycle in the District of Ithaca(U.S.A.) varies between 19 to 43 days and that there is a very marked tendency for the cycle to be lengthened out as the colder weather sets in. Gurney[15] too remarks that the life-cycle of A.mali requires three to four weeks and that it is slower in development in colder weather. While there have been suggestions that a genial temperature is likely to be necessary for the successful multiplication of A.mali, it is interesting to note, in a recent paper by Janche[18], in which he says that in Germany 'twigs infested with woolly aphis parasitised by Aphelinus mali were placed in autumn 1928 on apple-trees in the open, and in April and June 1929 the/

the Chalcid had survived the winter which was a very severe one'.

In conclusion it may be said that with additional material of the parasite and favourable conditions for rearing it, one might hope for its successful introduction in Scotland.

SUMMARY.

(i) For the Edinburgh District, the 'Woolly Aphis' wakes up in April from its winter sleep and continues its activity on the host plant - the apple - till the middle of November.

(ii) During this period of seven months, the aphis multiplies by the method of parthenogetic and viviparous reproduction.

(iii) During the early months of the summer apterous forms only are produced; but later from August onwards winged forms are being produced, and these also reproduce their kind parthenogenetically and viviparously.

(iv) Winged forms were observed flying to other apple plants, but they were never observed to fly and settle on the common British Elm. Potted plants of the Elm were artificially infected with the woolly aphis in apterous as well as winged stage, but none of these established themselves on the elm.

(v) No sexual stage of the woolly aphis - E.lanigera - was observed.

(vi) The winter was passed in wingless stage either in sheltered/

sheltered chinks and crevices of the apple plant above ground, or as Theobald and other observers have found, by crowling down the soil to the roots.

(vii) Damage is done to the host plant throughout the year, the Terrestrial parts being attacked in summer, the roots and the other subterranean portions in winter.

(viii) In the course of the paper is given a general description of the apterous female of E.lanigera, followed by a detailed morphological account of the winged female.

Abbreviations explained :-

a. = First anal vein.
abd. = abdomen.
ant. = antenna.
an.pl. = anal plate.
a.p. = anterior phragma.
c. = coxa.
cb. = cubital vein.
cl. = claws.
cn. = cornicles.
cst. = costal vein.
e. = eye.
e.c. = compound eye.
end. = endosternite.
f. = femur.
fr. = furrow.
hd. = head.
hk. = hooks.
hp. = hollow process.
k.p. = knoblike process.
lb. = labium.
lbr. = labrum.
m. = median vein.
md. = mandible.
mt. = metathorax.
mx. = maxilla.
oc. = ocellus.
og. = outgrowth.
ot. = ocular tubercle.
p. = prothorax.
pb. = proboscis.
pr. = process.
psc. = prescutum.
p.scl. = post-scutellum.
p.st. = prothoracic sternum.
p.pl. = prothoracic pleural plate.
p.tg. = prothoracic tergum.
rg. = ridge(in the sternum).
R.S. = Radial Sector.
sc. = scutum.
scl. = scutellum.
sc.m.a. = anterior scutal margin.
sc.m.p. = posterior scutal margin.
sh.pl. = shoulder plate.
sns. = sensoria.
sns.r. = sensory ring.
sns.p. = sensory pit.
sp. = spiracle.
sp.abd. = abdominal spiracles.
sp.mt. = metathoracic spiracle.

t. = trochanter.

tb. = tibia.

ts. = tarsus.

tp. = tube-like process.

wg. = wax-glands.

w.p. = wing-pads.

w.sl.= wing sclerites.

Explanation of Plates :-

Fig.1....Stem-mother of Eriosoma lanigera. x 54.

Fig.2....Apterous viviparous female of E.lanigera. x 54.

Fig.3....Apterous viviparous female, side view. x 75.

Fig.4....Head,showing mouth-parts. x 225.

Fig.5....Last two antennal joints showing sensoria. x 450.

Fig.6....Leg. x 112.

Fig.7....Wax-gland(apterous female). x 450.

Fig.8....Young stage. x 112.

Fig.9....Early nymphal stage of the Winged Female. x 54.

Fig.10...Later nymphal stage of the Winged Female. x 54.

Fig.11...Winged viviparous Female of E.lanigera. x 24.

Fig.12...Head(winged form) dorsal view. x 112.

Fig.13...Head(" ") ventral view. x 112.

Fig.14...Last two antennal joints, showing sensoria. x 450.

Fig.15...Prothoracic region. x 230.

Fig.16...Mesothoracic region. x 112.

Fig.17...Mesosternum. x 112.

Fig.18...Mesosternum(internally) showing Endosternite. x 230.

Fig.19...Endosternum viewed from anterior side. x 230.

Fig.20...Mesopleural sclerites. x 450.

Fig.21...Basal region of the front wing showing the wing-sclerites and their attachment to the scutal region. x 450.

Fig.22/

Fig.22...Ventral view of the base of the front wing. x 450.

Fig.23...Metasternum and Abdomen - ventral side. x 112.

Fig.24...Metapleural region showing the sclerites where the hind wings are attached. x 230.

Fig.25...Basal region of the hind wing. x 450.

Fig.26...Front wing. x 42.

Fig.27...Hind wing. x 112.

Fig.28...A part of the hind wing showing the hooks. x 450.

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Fig.29...Wax-gland of the Winged form.

Fig.30...The Egg of Aphelinus mali - the Woolly Aphis parasite. x 112.

Fig.31...The larva of Aphelinus mali. x 54.

Fig.32...The Pupa of A.mali. x 54.

Fig.33...The adult A.mali. x 65.

Fig.34...Parasitised woolly aphis showing the hole through which A.mali has escaped. x 54.

Fig.35...) Photographs showing the Woolly-aphis
Fig.36...) infection on the apple.

Fig.37...Photograph of the wire-gauze-cages and how they were fixed to the plant.

Fig.38...Photograph of an out-door apple tree with the cages fixed to the branches.

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PAPER II.

STRUCTURE and BIONOMICS

of

Trichocera maculipennis (meig.).

C O N T E N T S :-

(1) Introduction.

(2) Habits and Habitat of the larva.

(3) Life-history.

(4) Description of the various stages.

(a) Egg,

(b) Young larva,

(c) Fully developed larva,

(d) Pupa,

(e) Adult.

(5) Lettering and Explanation of Plates.

(6) Bibliography.

INTRODUCTION.

In the month of April 1928, a small box was received from Mr. Mackenzie of Ballindalloch, Banffshire. It contained some clinkers covered with a slimy evil-smelling substance. This odorous material was the refuse from the Craggonmore Distillery Works. Moving about in the slimy mass were a number of larvae. Dr. R. Stewart McDougall who received this material for investigation, reared the larvae, and the adults emerging were identified as Trichocera maculipennis.

This species, according to Edwards(8), has not been observed in Britain outside the Lowlands of Scotland. This fact, along with the interesting and somewhat unusual habitat of the larva, suggested the working out of the Bionomics of the species. This paper contains a study of the life-cycle and habitat of T. maculipennis, together with structural descriptions of the various stages. The work was carried out in the Entomological Laboratory of the University of Edinburgh, under the direct supervision of Dr. R. Stewart McDougall.

I wish to take this opportunity of offering my most sincere thanks to Dr. McDougall for his kindness/

kindness in assisting me, during the course of investigation, with information regarding literature and general technique, and also in obtaining for me a frequent supply of the material. I also wish to acknowledge my thanks to Mr. P.M.Innes, Manager of the Cragganmore Distillery Works, and to Mr.Charles McKenzie of Ballindalloch, for kindly supplying me with material and information, as well as for the great help they gave me when I visited the Distillery Works.

Trichocera maculipennis(meig.1818) is a Dipterous fly belonging to the Trichocerinae which itself forms one of the subfamilies of Tipulidae. Meigen(1818) was the first to find this species and name it as maculipennis, from its spotted wings. Since then, little or nothing seems to have been done regarding the structure or Bionomics of T.maculipennis although work has been done on other species.

It would not be out of place to state here the main features of the habitat of the Genus Trichocera in general, as studied by various observers. Perris[1] was the first to describe the larva of T.annulata, with notes on its life-history and habitat. The larvae of this species, as Perris says, are found in/

in the midst of decomposing vegetable matter; they live gregariously amongst rotten gourds and fungi of the Agaricus section. Perris further says that he found the fly to be very common during October, November and December at Mont-de-Marsau(South of France), everywhere upon hedges, manure, fungi, etc.

Others have recorded their observations on Trichocera species, and among them Keilin. His paper(5) is much more recent and quite exhaustive. With regard to the distribution of Trichocera, Keilin says that the flies are spread all over the world, that they are common in all temperate regions, and that one also finds them in cold regions. He also observes that Trichocera adults appear just at the approach of autumn and during winter, and that they are found dancing in groups, especially in favourable weather. His observations on the habitat of T.annulata, T.hiemalis and T.regelationis show that the larvae of these species are found in certain decaying fungi or under dead leaves in the garden or in places where organic matter exists in a state of decomposition. With regard to the habitat of T.regelationis, Rhynehart(9) writes that the larvae are found amongst rotting swedes and decaying portions of their roots; and that the eggs/

eggs are laid in the decaying tissue of the swedes.

From the foregoing details it will be clear that Trichocera species in general are found during autumn and winter, when most other adult flies are dead or hibernating; and that the Trichocera larvae are found feeding in decaying organic matter, that is, in habit they are scavengers. These statements will be of particular interest when later on I record my own observations on the habitat and life-history of T.maculipennis.

<u>HABITS and HABITAT of the LARVA of T. maculipennis.</u>

In order to arrive at a clear understanding of the question under consideration, it would be advisable to give here a short history of the origin of the Distillery refuse which forms the breeding place of this species. In the process of preparing the malt in the Distillery, barley is soaked in water, and in the presence of other conditions for germination, the ferment secreted by the cells of the scutellum acts upon the endosperm which is chiefly starch, and the starch is changed to sugar. It is this sugar the distiller wants and not young barley seedlings, and/

and therefore in due course, the germinating process is brought to an end. Cleaning follows to remove husks, etc., and then all is ground up into fine flour to which hot water is added. This malt, as it is called, is removed to a tank and yeast added, when fermentation follows. When the proper time has arrived, the alcohol is led off in one direction and the malt-yeast residue in another to a large open tank. Here much of the matter sinks to the bottom, and more or less solidifies to form a useful cattle-food. The water still containing impurities is led to another tank, pure water and lime being added. More solid matter settles down at the bottom and this has some use as manure. What is left over is fed to a reservoir near which are situated the so-called 'Filters'. The 'filters' contain 'clinkers' piled up to a height of 20 feet. Tubes lead the water with its impurities to these 'filters' where the impure water is sprinkled over the clinkers. Water filters down through the clinkers and is collected below in the basin running all round the base of the filters, and is drained ultimately into the river.

A slimy dark-looking, semifluid stuff, with a very unpleasant odour, remains behind attached to and/

and coating the clinkers; and it is in this slimy residue of the Distillery that the larvae of T.maculipennis were found in numbers. When the Distillery is in full working order this slimy refuse forms a thick layer over the clinkers, but all of it soon disappears as a result of the feeding habits of the maculipennis larvae.

While the larvae of T.maculipennis were easily the most abundant species, other Dipterous larvae were present playing the same part of scavengers. For example, the larva of the common moth-fly of Sewage works - Psychoda severini - was very common in the Distillery refuse.

The adults and the larvae of T.maculipennis were first observed by the Manager of the Distillery in Spring 1925, and their presence was recorded till the middle of September of that year. Similar observations were made during 1926 and 1927. The continued reappearance of these flies and the peculiar habits of their grubs suggested Mr.P.M.Innes and Mr.C.McKenzie to send material to Dr.R.Stewart McDougall in April 1928 for identification. The investigation which this paper records is the result.

The observations of the Distillery manager and/

and my own may be summarised thus :-

(1) The larvae of T.maculipennis are first found at work about the middle of March every year.

(2) The adults begin to appear about the beginning of April and can be found till the end of September.

(3) From October till March adult flies have not been observed.

(4) The larvae are voracious eaters and feed upon the waste refuse of the Distillery.

(5) During the period of their appearance the adult flies can be found in large numbers in the filters, flying about and resting on the slimy refuse.

(6) In the Laboratory the adults were kept alive for about 18 days on honey and water.

(7) An examination of the Distillery refuse during October, November, December, January and February, indicated the presence of T.maculipennis at no stage in the refuse.

LIFE - HISTORY.

In the first week of May 1928 I had the first opportunity to examine the material of Trichocera maculipennis, sent from Cragganmore Distillery. Quite a number of larvae of this insect were found moving/

moving about in the slimy refuse. A few days later, some of the larvae, having reached their fully-grown stage, were found pupating and a week or so later adults issued. I tried to breed out a new generation of this insect, in the Laboratory, by caging together male and female adults, but it was not very successful during that summer. Pairing took place in the breeding cages and eggs were laid upon the damp soil offered in the experimental cages, but none of the eggs hatched. From the successful breeding in the next year, one may say that the nidus for these 1928 eggs was unfavourable.

During 1929, the material came to us rather late in the month of July. About 25 larvae were found in the material, some of which pupated in time, and after a week adults began to come away. I caged together males and females and after a few days the fertilised females laid eggs, and with these I was able to follow up the complete life-cycle of this fly, from egg to adult.

The various details are as follows:- An adult female appearing on August 11, 1929, was caged with a male that issued on 22nd of August 1929. Special care was taken this time to offer, as far as possible/

possible, a natural surrounding for the fly to lay her eggs, and give favourable conditions for their subsequent development. For this purpose the ground surface of the cage was covered over with a thick layer of ordinary soil mixed with the slimy, odorous refuse from the Distillery. This was kept distinctly wet, throughout the experiment, and throughout retained an appreciable odour.

Pairing took place, and on 26th of August the female began to show signs of sluggishness, with an inclination to walk over the surface of the damp soil in the cage rather than fly about. The next morning the female was noticed laying eggs, singly as well as in masses, on the wet soil. The mode of laying eggs was rather interesting. While walking over the surface of the prepared soil, the female would suddenly stop. The terminal portion of her abdomen which, while she was walking, was obliquely inclined to the surface, became bent under on itself, so that the ovipositor was carried forward under the abdomen. The ovipositor then was suddenly thrust down in the soil. A minute passed in this position, and then suddenly the fly pressed herself to the ground and remained in this position for two minutes. During/

During this time the egg was laid. The female then recovered her original position, straightened her abdomen and began to walk forward over the soil. The number of eggs laid by this female was about 40; the maximum number laid by another fertilised female was 124. The females died after laying their eggs.

The newly-laid egg(fig.1) is elongated oval in shape, with a transparent shell enclosing the white contents. After five or six days, the egg shell broke by a vertical slit at its anterior end and the young larva hatched.

The newly-hatched larva (fig.4) began at once to move about and feed. Consequently growth in size was rapid. By 25 days the larva was full-grown and ready for pupation. Before it pupated the larva stopped feeding and became sluggish. Its body was noticed a little contracted. It then buried itself just beneath the surface of the soil. After a short quiescent stage the larva moulted and pupated. The moulted skin was often found attached to the hind end of the mummy-like pupa.

Normally the pupa (fig.24) is inactive, but if irritated or placed in uncongenial conditions it exhibits wriggling movements of its body. When, for instance/

instance, the soil round about the pupa was dug up a wriggling movement of its body followed and attempts were made to avoid the light. Just before the emergence of the adult fly, the subterranean pupa, by means of the blunt backwardly directed spines on its body, pushed itself up through the moist soil and took up a position, with the head just above the surface of the soil. This position makes it easy for the emerging adult to escape safely from the pupal skin. The pupal life lasted from 7 to 9 days. When the adult was ready to emerge, a slit occurred along the mid-dorsal line of the pupal thorax; the adult fly slowly projected its head, and gradually the thorax and abdomen were freed; the legs were the last to free themselves from the pupal sheaths. The whole process from the breaking of the pupal slit to the complete emergence of the adult took not more than five minutes.

The following are some of the records bearing on the life-cycle of this fly :-

	I.	II.
Male and female caged together	Aug.22,1929	Aug.24,1929
Eggs laid	" 27	" 29
Preoviposition period ...	5 days	5 days
Larvae hatched	Sep.2,1929	Sep.3,1929
Egg-stage period ...	6 days	5 days

The larval period on the average was 27 days; e.g., a larva which hatched on the 2nd of September 1929, and was closely observed, pupated on the 29th of September in the temperature of the Laboratory.

Pupal Period.

	Date of Pupation.	Date of Adult emergence.	No. of Days.	Sex.
(1)	28. 5. 28	4. 6. 28	7	♂
(2)	6. 6. 28	14. 6. 28	8	♂
(3)	2. 7. 29	10. 7. 29	8	♀
(4)	2. 8. 29	11. 8. 29	9	♀
(5)	11. 8. 29	19. 8. 29	8	♀
(6)	14. 8. 29	22. 8. 29	8	♂
(7)	17. 8. 29	24. 8. 29	7	♂

Length of life of the Adult Fly.

	Date of Emergence.	Date of Death.	Length of Life.	Sex.
(1)	6. 6. 28	19. 6. 28	13 days	♂
(2)	6. 6. 28	21. 6. 28	15 "	♀
(3)	6. 6. 28	23. 6. 28	17 "	♀
(4)	7. 6. 28	23. 6. 28	16 "	♂
(5)	11. 7. 29	21. 7. 29	10 "	♂
(6)	11. 7. 29	23. 7. 29	12 "	♂
(7)	11. 8. 29	27. 8. 29	16 "	♀
(8)	14. 8. 29	29. 8. 29	15 "	♀

From the above table the life-cycle of Trichocera maculipennis, from the time the egg is laid to/

to the time the adult fly emerges, took about 40 to 42 days, under Laboratory conditions, at an average temperature of 60°F. The egg-stage lasts from 5 to 6 days; the larva takes 25 to 30 days to complete its growth. The pupal stage extends over 7 to 9 days. The adults fed in the cages on honey and water lived from 10 to 17 days.

DESCRIPTION of the VARIOUS STAGES.

Egg:- The egg of T.maculipennis (fig.1) is creamy white in colour, elongated oval in form, bluntly pointed at each end and thicker in the middle. The surface of the egg-shell is granular in appearance. Length of the egg is .46 m.m., breadth .17 m.m.

The various changes observed in the growth of the newly laid egg, before the newly formed larva hatched out, are as follows:- The egg contents of a newly laid egg, after about 20 hours, detach themselves from the two blunt ends of the egg-shell and collect towards the centre (fig.2). After two days,(fig.3) the central mass is seen divided into two portions; an anterior smaller and round(a.p.), and a posterior larger and elongate(ps.p.). The smaller anterior portion/

portion begins to differentiate itself into the head region of the larva, while the larger posterior one develops into the body of the future larva. After five or six days the newly formed larva hatches out by a vertical slit in the anterior region of the egg-shell.

Young Larva:- The newly hatched larva (fig.4) measures about 1.27 m.m. in length, and is brownish-grey in colour. The head, comparatively large, is not much chitinised. The chitin of the head, being therefore somewhat transparent, the pharynx and its working could be observed under the binocular microscope. The antennae(ant.) are easily noticeable, and so are the eye-spots(e.). The latter are situated at the sides of the antennae and are marked by the presence of red pigment. When examined under the high power of the microscope, the body of the early larva is seen coated with very fine hairs. The segmentation of the body is prominent, due to the presence of slightly chitinised brownish rings which occupy the intersegmental region. Secondary segmentation is also noticeable, but not to the same degree as in the case of the fully developed larva. Prothoracic spiracles are wanting. The hind pair of spiracles/

spiracles(h.sp.) borne by the last segment, are situated between an upper and a lower pair of fleshy lobes (f.l.). The lobes are covered over with long fine hairs, except on their inner sides. The tracheal trunks, which can be traced from the hind spiracles, owing to their being visible through the transparent integument, run forward, one on each side of the body. The nervous system together with its segmental arrangement of ganglia, can also be seen clearly through the chitin, and similarly one sees the alimentary canal with its pale-coloured contents.

FULLY DEVELOPED LARVA.

(a) External Characters:-

(i) Body:- A fully developed larva of T.maculipennis (fig.5), stretched to its full length, measures 10 m.m. in length by 1.3 m.m. in breadth. It is yellow-white in colour, and its body is slightly flattened dorso-ventrally. A free chitinous head region is followed by a body of 11 segments, there being little or no demarcation between thorax and abdomen. Each segment of the body is further divided into two or three pseudo-segments, owing to the presence of transverse folds. The first four segments of the body, behind the head, are divided each into two secondary/

secondary segments; each of the next six is divided into three; and last one into two secondary segments. The lateral margins of the body are wavy in form, owing to the secondary segmentation which is not limited only to the dorsal surface of the body. The integument of the body, though thinly chitinised, is tough in consistency, and is covered with rows of fine hairs; a few stout bristles are scattered here and there.

The larva is legless, but under the microscope two clear spots are seen on the under surface of each of the first three segments of the body behind the head (fig.6). On each of these spots one finds four bristles two of which are stouter and longer than the other two.

The first segment of the body - the prothoracic segment - bears a small spiracle(p.sp.) on each side dorso-laterally. The last segment of the larva (fig.7) carries on its dorsal surface two pairs of fleshy lobes(f.l.) of which the posterior pair is longer and larger than the other. The inner faces of these lobes are formed of a layer of yellowish chitin, distinctly thicker than the surrounding chitinous integument. On their outer surfaces, the lobes carry/

carry a series of long bristles disposed more or less like a fan. Between these lobes, nearer the base of the dorsal pair, are situated two spiracles(h.sp.) brownish-black in colour and much bigger in size than the prothoracic pair. In the living condition, the so-called spiracular lobes(f.l.) were often noticed to close in towards each other and thus protect the spiracles, whenever the latter were exposed to the danger of being choked by the introduction of foreign material.

On the ventral side of the last segment of the larva lies a circular anal plate(fig.8,9,an.pl.) through which the anus opens to the exterior by means of a four-grooved anal aperture(an.gr.).

(ii) Head.(fig.10,11) :- The head of this larva, being free from the rest of the body, is partly retractible into the prothoracic segment. It has the form of a chitinous capsule broader at the hind end, and longer on the dorsal than on the ventral side. The posterior edge of this capsule is thickly chitinised. The position occupied by the clypeus(cly.) can be made out only by means of a faint incomplete suture lined by a row of spines on either side.

The mouth is situated ventrally. The mouth/

mouth-parts are: a labrum(lbr.) and epipharynx(ep.) on the dorsal side and in front of the mouth; a pair of mandibles(md.) at the sides; below and behind these, a pair of maxillae(mx.) and ventrally the labium(lb.).

The labrum (fig.10,11,12) is a prolongation of the clypeus. Anteriorly it merges into the epipharynx(ep.) which is bent ventrally. At the point of the bend, there is a definite joint(j.) dividing the labrum proper from its ventrally curved epipharyngeal portion.

The epipharynx(ep.) is rather a complex structure. Figure 12 will help to explain it. It is somewhat round in form, and covered with hairs some of which are conspicuously bristle-like on either side of the median line. The median line shows also a few small papillae(pal.) which may be of a sensory nature(5). Apically the median line ends in a small blunt process(pr.) below which is situated another larger U-shaped prolongation(U.pr.) covered with stiff spines and paillae(pal.). At each side of this U-shaped prolongation is seen a chitinous dentate or comblike structure(cmb.). The latter possesses six prominent teeth, and is continued below carrying a varying number of pointed spines.

The/

The term 'epipharynx' used in the above description is that used by Rhynehart[9] in his paper on T.regelationis. While describing the 'comb-like' structure mentioned above, Rhynehart[9] finds, in the case of the larva of T.regelationis, only six chitinous teeth in each comb. Keilin[5] in his description of the larva of T.hiemalis, does not record the exact number of teeth.

Mandibles (fig.13,14). At the sides of the labrum viewed from the dorsal side, are situated a pair of well-developed and strongly chitinised mandibles. Each mandible consists of two portions; a large proximal position(p.p.) and a relatively small distal one(d.p.). The basal margin of the proximal portion is somewhat semicircular in outline and gives off a curved chitinous process(dr.cd.) on its dorsal side, termed the 'dorsal condyle' by Rhynehart in T.regelationis. This dorsal condyle by which the mandible is articulated to the cephalic capsule, serves as a hingelike mechanism for the dorso-lateral movement of the mandible. The inner side of this proximal portion of the mandible(p.p.), has a concave depression(cn.d.) in which are present a bunch of long fanlike hairs. The same depression gives attachment to/

to the large adductor muscles(add.m.). A little in front of this concave pit, verging on the sides of the mouth, is seen a dentate chitinous structure(dt.st.) provided with one large tooth(t.) and five smaller ones. On the outer convex side of this proximal portion of the mandible, there are two stout, many-branched bristles; an unbranched bristle is found on its ventral surface.

The distal portion of the mandible(d.p.) is deeply chitinised and strongly toothed. The teeth(t.) 7 to 8 in number, are arranged in a fanlike fashion, and curve somewhat inwards towards the mouth-aperture. The outer base of this distal dentate structure(d.p.) is lined with bunches of long stout hairs.

Maxillae(fig.11,15):- Below and behind the mandibles are situated a pair of maxillae(mx.). Each maxilla is composed of a proximal portion(mx.p.p.), and a distal one(mx.d.p.). The proximal portion can be said to be homologous with fused cardo and stipes(9). It carries on its ventral surface bunches of long yellow-coloured hairs arranged in small transverse rows. Amongst them stands out one stout backwardly bent spine(spn.).

The distal portion of the maxilla is divided, by means of an incomplete vertical notch(v.nt.), into an/

an outer portion homologous with the maxillary palp (mx.pl.) and an inner one bordering the mouth. The maxillary palp has on its ventral surface a conspicuous pit(sns.p.) containing about 16 sensory papillae. All around this pit the palp has a coating of fine hairs which near the anterior margin are replaced by a few longer ones. The inner portion of the maxilla (d.p.) bears two or three blunt tooth-like processes(t.). In addition to these, it also carries a few stout spines which point inwards towards the mouth-cavity. In amongst these spines are numerous shorter and longer hairs. A little outer to the maxillary teeth(t.) between them and the vertical notch(v.nt.) is seen a sensory area(sns.a) carrying a few blunt sensory papillae surrounded by fine long hairs.

Rhynehart[9] in his description of the larval mouth-parts of T.regelationis, finds in the sensory area(sns.a.) described above, a homology with the 'galea', while the teeth-bearing maxillary region mentioned above, he likens to the 'lacinia'.

Labium (fig.15). The labium of T.maculipennis larva is less chitinised, and probably functions more as a sensory organ than aiding in mastication[5]. On its outer surface are seen two prominent swellings; an/

an anterior one(end.), and a posterior one(exo.), named the endolabium and the exolabium respectively[5]. The endolabium bears small tufts of very minute hairs on its sloping surface. The exolabium also carries similar tufts of minute hairs, but in addition to these there are present 10 to 11 sensory papillae on its dome-like surface. The posterior part of the labium, which is fused to the proximal portion of the maxilla on either side, is covered over with bunches of long yellow-colored hairs arranged in transverse rows.

In his description of the labial region of the larva of T.regelationis, Rhynehart[9] determines the exolabium of Keilin[5] as labium proper, and Keilin's endolabium as the hypopharynx. Moreover, he finds in one pair of the sensory papillae described above as present on the exolabium, a homology with a reduced labial palp.

Antennae (fig.16):- The antennae of this larva are situated in small circular pits in the dorso-pleural region of the head-capsule, a little behind the base of the mandibles. Each antenna(ant.) consists of two parts; a basal joint(bs.j.), carrying a series of blunt sensory papillae(pal.), and a terminal one(t.j.) having the form of an inverted bell.

Eye/

Eye (fig.16) :- In the neighbourhood of the antenna on each side are three transparent oblong dots(e) arranged in a triangle and surrounded by a few stiff spines. They constitute the eye of this larva. It may be mentioned here that while a red pigment was noticeable in this eyespot of the early larva, no trace of red was visible in the case of the full-grown larva.

The internal skeleton of the head-capsule consists of a pair of chitinous rods which take their origin internally near the mandibular base and descend down backwards to articulate with the ventral posterior corners of the capsule.

(b) Internal Structure:-

Under a fairly tough cuticle the body-wall is formed mainly of longitudinal muscles grouped in definite bands. The body-cavity of the larva is filled with fat-body arranged in two much-folded semi-cylindrical masses(fig.17,fts.) which envelop the alimentary canal throughout its whole length.

The Digestive System(fig.17) :- The alimentary canal in this scavenger type of larva, when dissected out, measures a little longer than the body. It is divided into the foregut(f.g.), the midgut(m.g.) and/

and the hindgut(h.g.), and is provided with salivary glands(sl.gl.) and malpighian tubules(mlp.).

The mouth which opens on the ventral face of the head-capsule, is formed by the labrum and epipharynx above and in front, the mandibles and maxillae at the sides and the labium below and behind. It leads into the chitinous pharynx(ph.) which presents somewhat a peculiar structure. Figures 18, 19, will help to explain it. Looked at from the side(fig.19), the pharynx suggests the shape of the upper portion of a funnel, with its stalk comparable to the oesophagus(oes.) issuing from it ventrally behind. Examined from the dorsal aspect(fig.18), the inner sides of the pharynx, as in the case of the funnel, close in or narrow down towards the central cavity(oes.op.) which leads into the oesophagus. One also sees these inner sides of the pharynx lined with rows of fine hairs(r.h.) directed downwards towards the oesophageal opening. Internally, the pharynx on its dorsal side, is covered over with a chitinous shield-like lining(fig.12,19,sh.l.) open in front where it is attached to the upper side of the mouth-cavity in front of the epipharynx. This shield-like cover is lined on its inner face with rows of fine hairs directed backwards. The pharynx is held/

held in position and worked by means of muscles attached to the wall and to the internal skeleton of the head-capsule.

Following the pharynx comes the oesophagus (oes.) which has a chitinous lining, and is supported near its origin by eight chitinous bands(cht.b.) running longitudinally along its wall. The oesophagus is continued behind as far as the metathoracic region, where it leads into the midgut by means of a constricted valvular opening(oes.vl.).

The midgut(m.g.) which is the longest portion of the alimentary canal of this larva, is strongly muscular. Broadest in front, it gradually narrows behind to meet the hindgut(h.g.).

The hindgut(h.g.) which occupies the hind third of the larva, is formed of two parts; an anterior and a posterior. The anterior (fig.17) is a round swollen portion lined with an epithelium of flat cells. It is this portion into which open the malpighian tubules(m.lp.) by means of two common ducts. The posterior portion of the hindgut is muscular and tubelike and a little bent before it reaches the anus. The alimentary canal opens to the outside through a four-grooved anal aperture(fig.17,9,an.gr.).

Associated with the digestive system, are

the/

the salivary glands(sl.gl.) and the malpighian tubules(mlp.). The salivary glands are very minute and lie on either side of the oesophagus. They have the shape of elongated sacs (fig.20) folded upon themselves. The end of each gland is attached to the abundant fatty tissue, by means of small threads. The epithelium of these glands shows large nuclei(n.) with beaded chromosomes(bd.chr.). The ducts from each gland join to form a common duct(sl.d.) which, passing ventrally to the pharynx, opens between the endolabium and exolabium. The common duct shows distinct striae and may therefore be mistaken for a tracheal tube.

The malpighian tubules are four in number and they enter the front portion of the hindgut by means of two common ducts. The tubules are very long and convoluted and intimately bound up with the diffuse fat body. Consequently it is often very difficult to dissect them out entire. Each tubule (fig.21) consists of large cells(cl.) arranged in such a way that the tubule presents a necklace-like appearance. The contents of the tubules show the presence of a number of small deeply staining spherical bodies surrounding the malpighian cells.

<u>Nervous system</u> :- The nervous system consists/

consists of a brain made up of the supraoesophageal ganglia (fig.22,sp.oes.g.), a suboesophageal ganglion (s.oes.g.) and a cord with three thoracic(th.g.) and eight abdominal ganglia(abd.g.). The two-lobed brain lies in the hind region of the head-capsule; the suboesophageal ganglion which lies below the brain, is connected with the latter by right and left commissures forming a ring through which the oesophagus passes behind. The thoracic ganglia(th.g.) are comparatively larger and are situated at short distances from each other. The abdominal ganglia(abd.g.) are somewhat smaller; the ganglia of the various segments are rather wide apart from each other, save the last two which lie close together.

Dissection reveals the heart as a very thin transparent tube lying immediately below the dorsal integument.

Respiratory system :- The respiratory system of the larva of T.maculipennis, unlike other Tipulid larvae, consists of two pairs of spiracles. The front pair is carried on the prothoracic segment (fig.23_c), and the hind pair is borne on the terminal one. The front spiracles are not found in the newly-hatched larva, but they are quite well-developed in full-grown larva.

The/

base and with two free distal arms(ar.). The arms are bent upwards and between them a small blunt process(pr.) runs forward. Viewed from the anterior side, the endosternite appears like the vertical section of a champagne glass (fig.19). Viewed from the sides the stalk of the sternite appears rather flat at its point **of** origin, and so are the arms seen from above.

The pleural region of the mesothorax(fig.16) is most complex and is composed of a number of chitinised pieces and plates involved in the attachment and support of the mesothoracic pair of wings. Arising from the pleural margin of the shoulder plate (sh.pl.) can be seen a plate-like chitinous structure divided into an anterior flat portion(A.) and a posterior conical rodlike one (B.). Both of these parts are thickly chitinised thouh not uniformly. From the dorsal margin of the anterior plate (A.) two structures arise; one, the anterior, in its relative position, (C) is semicurved with forked ends by means of which it gives support to the basal portion of the anterior notal wing-process of the scutum(sc.m.a.). The other structure (fig.16,20.D.), posterior in position to the first, is somewhat interesting. Situated/

is brought about by the violent treatment inseparable from section-cutting technique, is of opinion that 'it represents a line of incomplete fusion between two portions of the plug which were formerly separate'. Moreover, Wardle does not find the presence of any sieve-plate structure in the surrounding chitinised membrane mentioned by Keilin.

Leaving out of account the results of microtome sections which in the case of the larva of T. maculipennis show the presence of a vertical slit, careful dissections of the spiracles of the same larva show that there is a definite narrow wavy vertical slit passing through the stigmatic plug and communicating with the inner stigmatic chamber situated at the base of the plug.

The front and hind spiracles are connected to each other by means of two fairly large tracheal trunks running along the dorso-lateral margins of the body. Various branches are given off from these trunks, which sub-branch and form a network throughout the body.

Pupa :- The pupa of T.maculipennis (fig.24) is about 8 m.m. long. It is yellow-brown in colour and the body is curved a little in the abdominal region. The breathing horns are well-seen on/

on the dorsal side in the prothoracic region. The legs, wrapped in sheaths, are glued down to the body, on the ventral side, and so are the wing-pads(fig.24, wg.pd.) at the sides. The male pupa is a little smaller than the female pupa, and the terminal portions of both show distinctive sexual characteristics as seen in figures 25 and 26. The body of the pupa has a number of small spiny projections(spn.) which are directed backwards. These help the pupa to make its way upwards to the surface of the soil before the adult issues from the pupal skin.

Adult :- (fig.27). The adult T.maculipennis is quite a large fly measuring about 8.5 m.m. in length and 20 m.m. in expanse of wing. The male is a little smaller being about 7 m.m. in length and 19 m.m. in breadth with expanded wings. The general specific characters which distinguish maculipennis from other species of Trichocera, are according to Pierre[10] the following:-

(i) Abdomen uniformly darkish.

(ii) Anterior cross-vein with a distinct patch round it.

(iii) A distinct cloud on and below the base of the radial sector.

The/

The first of these characteristics separates T.maculipennis from T.annulata; the second, from the rest of Trichocera species except regelationis; while the third distinguishes it from T.regelationis itself.

SUMMARY.

(i) The larva of Trichocera maculipennis was found in the Cragganmore Distillery refuse, at Ballindalloch. It feeds upon the slimy, dark-coloured, odorous residue in the Distillery filters, and thus, in habit, plays the part of a scavenger.

(ii) The larvae are found at work in the dirty waste refuse from March onwards till the end of September.

(iii) The adult fly begins to appear in early April, and can be found in large numbers in and near the filter-houses till the end of September. From October till March, adult flies have not been observed in the said locality.

(iv) A continued examination of the Distillery refuse during the autumn and winter months, indicated the presence of T.maculipennis at no stage in the refuse.

(v) The life-cycle of T.maculipennis, from the time the egg is laid to the time the adult fly emerges, requires about 40 days under Laboratory conditions. The egg-stage lasts from 5 to 6 days; the larva requires about 25 days to complete its growth; the pupal stage extends over a week or so.

(vi) /

(vi) The latter part of the paper deals with the general morphology of the egg, the larva, the pupa and the adult of T.maculipennis. A more detailed account of the anatomy of the fully-developed larva is also described.

Lettering explained.

abd.g.	= abdominal ganglia.	ex.o.	= exolabium.
abd.m.	= abductor muscles.	f. l.	= fleshy lobes.
add.m.	= adductor muscles.	f.l.a.	= anterior fleshy lobe.
an.gr.	= anal aperture.	f.l.p.	= posterior fleshy lobe.
an.pl.	= anal plate.	f. g.	= fore-gut.
a. p.	= anterior portion.	f.ts.	= fatty tissue.
ant.	= antenna.	hd.	= head.
bd.chr.	= beaded chromatin.	h. g.	= hind-gut.
br.bl.	= branched bristles.	h. sp.	= hind spiracles.
br. hn.	= breathing horns.	j.	= joint.
bs.j.	= basal joint.	lb.	= labium.
cht.b.	= chitinous bands.	lbr.	= labrum.
cl.	= cell.	md.	= mandibles.
cly.	= clypeus.	m.g.	= mid-gut.
cmb.	= comblike structure.	mlp.	= malpighian tubules.
cn.d.	= concave depression.	mx.	= maxilla.
d. p.	= distal portion.	mx.pl.	= maxillary palp.
dr.cd.	= dorsal condyle.	n.	= nucleus.
dt.st.	= dentate structure.	oes.	= oesophagus.
e.	= eye.	oes.op.	= oesophageal opening.
eg.m.	= egg mass.	oes.vl.	= oesophageal valve.
eg.s.	= egg-shell.	pal.	= papillae.
end.	= endolabium.	ph.	= pharynx.
ep.	= epipharynx.	pr.	= projection or process.

p.p./

p.p. = proximal portion.

p.sp. = prothoracic spiracles.

ps.p. = posterior portion.

r. h. = row of hairs.

sh.l. = shield-like lining.

sl.d. = salivary duct.

sl.gl. = salivary gland.

sns.p. = sensory pit.

sns.a. = sensory area.

s.oes.g.= sub-oesophageal ganglion.

sp. = spiracles.

spn. = spines.

sp.oes.g. = supra-oesophageal ganglion.

st.br. = stigmatic bars.

st.ch. = stigmatic chamber.

st.pg. = stigmatic plug.

st.rm. = stigmatic rim.

st.sl. = stigmatic slit.

t. = teeth.

th.g. = thoracic ganglia.

t.j. = terminal joint.

U.pr. = U-shaped projection.

v.nt. = vertical notch.

wg.pd. = wingpads.

EXPLANATION of PLATES.

Fig.1.... Newly laid egg of Trichocera maculipennis. x 112.

Fig.2.... Egg of T.maculipennis after 20 hours. x 112.

Fig.3.... Egg " " " after 2 days. x 112.

Fig.4.... Newly hatched larva of T.maculipennis. x 112.

Fig.5.... Fully developed larva. x 10.

Fig.6.... Thoracic under-surface of the larva, showing the clear spots carrying each four bristles. x 54.

Fig.7.... Spiracular region of the larva, showing the hind spiracles and the spiracular lobes. x 112.

Fig.8.... Anal area of the larva. x 112.

Fig.9.... Anal plate, with anal openings. x 112.

Fig.10... Head-capsule of the larva, dorsal view. x 112.

Fig.11... " " " " " , ventral view. x 112.

Fig.12... Epipharynx of the larva. x 450.

Fig.13... Mandible, dorsal view. x 450.

Fig.14... Mandible, ventral view. x 450.

Fig.15... Maxillae, Labium. x 225.

Fig.16... Antenna, eye. x 450.

Fig.17... Alimentary canal. x 25.

Fig.18... Pharynx(inner view). x 225.

Fig.19... Pharynx(side view). x 225.

Fig.20... Salivary gland. x 112.

Fig.20a...Nucleus highly magnified. x 450.

Fig.21... A portion of Malpighian tubule. x 450.

Fig.22/

Fig.22.... Nervous system. x 26.

Fig.23a... Hind-spiracle of the larva. x 600.

Fig.23b... Vertical section of the hind-spiracle. x 600.

Fig.23c... Front-spiracle. x 450.

Fig.24.... Pupa of T.maculipennis. x 24.

Fig.25.... Female genitalia of Pupa. x 112.

Fig.26.... Male genitalia of Pupa. x 112.

Fig.27.... Adult fly - Trichocera maculipennis. x 6.

Fig.28.... A photograph showing the tanks to which the Distillery waste water is led.

Fig.29.... Photograph of the three filter-houses.

Fig.30.... Photograph of one of the filter-houses.

Fig.31.... A near-view of the basal part of the filter-house showing the clinkers inside and the small holes through which water trickles down in the basin below.

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